Journal of Forensic and Legal Medicine 17 (2010) 18–25

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/jflm

Original Communication

Diatomological mapping of water bodies for the diagnosis of drowning cases

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ARTICLE INFO

Article history:
Received 18 January 2009
Received in revised form 1 June 2009
Accepted 1 July 2009
Available online 15 August 2009

Keywords:
Diatoms
Drowning
Diatomological maps
Drowning site and water body

ABSTRACT

Forensic diatomology plays an important role in solving mysteries of drowning cases. The diatomology contributes significantly not only in determining the mode of death but also in determining the site of drowning. Presence of sufficient number of diatoms in vital distant body organs can establish ante-mortem drowning up to a certain extent. Question about the exact site of drowning is mostly raised particularly when circumstantial evidences are not clear about the drowning site or drowning site itself is not there. Distribution of diatoms in any water body, and their correlation with the diatom species recovered from the drowned body can be a method of choice to resolve the questions related to drowning site. Analysis was undertaken in order to record the significant variation in diatom diversity in the 10 (selected) different types of water bodies in Punjab (India) during different seasons (summer, autumn, winter and spring). This comparative study was conducted for two years. The data so obtained has been utilized to generate Diatomological Maps, which can be helpful in diagnosing the suspected drowning cases occurring in a particular area and characterization of different water bodies.

1. Introduction

Diatoms are group of unicellular algae that have very useful applications in Forensic investigations of drowning cases especially in establishing cause and mode of death i.e. ante-mortem and post-mortem drowning. The presence of tiny aquatic diatoms in a dead body has long been held by some to be a clear indicator of death by drowning. If analyzed both quantitatively and qualitatively through a diatom test, can lead not only to a more direct determination of the cause of death, but also pinpoint the site of a suspected drowning.[3–7,9,10,12]

Punjab is a land of canals, rivers, ponds and lakes, which offers an invite for drowning. Every year a large number of drowning cases are reported in Punjab.[13] Sometimes the drowned bodies are found suspiciously floating in these water bodies. In those cases, the Forensic Scientist has to give opinion whether the particular case is of *ante-mortem* or *postmortem* drowning. Along with this, another equally important question to be answered is that if the death really took place at that site from where the body was found. It imparts further necessity for the precise localization of site of drowning particularly

(i) when the body is found on land and no reference water body is available, and

(ii) when the body is found away from the actual site of drowning may be due to flow of water or any other reason.

Therefore search for the putative site of drowning becomes a thrust area in the Forensic investigations. Diatom and algal communities can vary from one water body to another. Water bodies with similar chemical and physical compositions develop similar but not identical diatom community. Various genera and *species* of diatoms establish themselves within the specific water bodies based on their nutrient and light requirements and therefore they can differ from one water body to another both qualitatively and quantitatively with climatic or seasonal changes. Some local factors like mineral content of water, temperature, water stratification, acidity, the distance from shore, the depth of sea and the tide, etc. do effect the diatom concentration in any water body.[3,7,11,12]

"Continuous River Monitoring of the diatom texa" can also be a suitable tool for generating Diatom profiles, which can be used not only as standards for the purpose of comparison with the diatom flora found in the tissues of drowned victim[5] but also can be utilized to generate *Diatomological Maps* (*D-Map*). These *Diatomological Maps* (for a particular water body) besides recording the profiles of diatom flora of any water body[10] also document various commonly occurring, seasonal and rare or site-specific diatoms *species* observed in different seasons.

So, the present study was carried out to record diatom diversity in the selected 10 different types water bodies of Punjab (India) during different seasons (summer, autumn, winter and spring) continuously for two years. The database obtained was used to create the *Diatomological Maps* (*D-Map*) for every water body.

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doi:10.1016/j.jflm.2009.07.016

2. Materials and methods

Keeping in mind the sensitivity of the places, the following 10 different water bodies spread over different locations of Punjab state (India) were selected for the diatomological mapping:

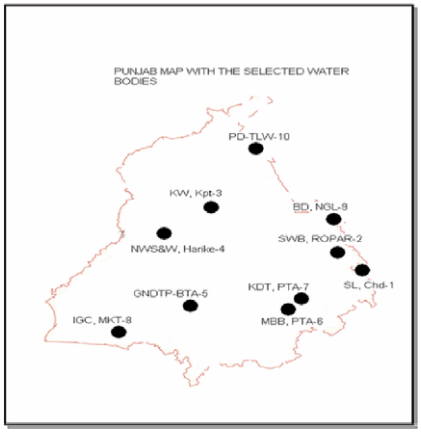
1. Sukhna Lake Chandigarh (SL, CHD-1)
2. Sutlej Water Body, Ropar (SWB-RPR 2)
3. Kanjli Wetland, Kapurthala (KW, KPT-3)
4. National Wildlife Sanctuary & Wetland, Harike (NWS&W, HRK-4)
5. Guru Nanak Dev Thermal Plant, Bathinda (GNDTP, BTH-5)
6. Main Bakhra Branch, Patiala (MBB, PTA-6)
7. Kali Devi Talab, Patiala (KDT, PTA-7)
8. Indira Gandhi Canal, Lambi-Mukatsar (IGC, MKT-8)
9. Bakhra Dam, Nangal (BD, NGL-9)
10. Pong Dam, Nangal (PD, TLR-10)

The physical and chemical descriptions of these selected water bodies have been given in Picture 1 and Table 1, respectively.

2.1. Collection of water samples

The water samples were collected from 10 different selected water bodies (which include 1 – Lake, 2 – ponds, 3 – canals and 4 – rivers) continuously for two years from June 2005 to March 2007 in two phases. All the samples were collected with a gap of three months covering four seasons i.e. winter, spring, autumn and summer. Eight collections were made during a span of two years. The dates of sample collection in both the phases (years) were kept almost same.

Water samples were collected in properly sterilized and serially marked one liter capacity plastic bottles from the all the sides of all water bodies. Lakes have basically four sides, while river and canals had only two sides. The pH of the samples was recorded and preserved as such for the further analysis.



Picture 1. Showing location of water bodies in Punjab state (India) map. (1) Sukhna Lake Chandigarh (*SL, CHD-1*). (2) Sutlej Water Body, Ropar (*SWB-RPR 2*). (3) Kanjli Wetland, Kapurthala (*KW, KPT-3*). (4) National Wildlife Sanctuary & Wetland, Harike (*NWS&W, HRK-4*). (5) Guru Nanak Dev Thermal Plant, Bathinda (*GNDTP, BTH-5*). (6) Main Bakhra Branch, Patiala (*MBB, PTA-6*). (7) Kali Devi Talab, Patiala (*KDT, PTA-7*). (8) Indira Gandhi Canal, Lambi-Mukatsar (*IGC, MKT-8*). (9) Bakhra Dam, Nangal (*BD, NGL-9*). (10) Pong Dam, Nangal (*PD, TLR-10*).

2.2. Extracting and analysis of diatoms

Approximately 200 ml of water sample was transferred into an acid washed 250 ml glass beaker. Samples were added with 40–45 ml of concentrated nitric acid (HNO_3) and a pinch of Potassium dichromate $K_2Cr_2O_7$. Then samples were allowed to stand undisturbed for 2 h. These samples were transferred to properly label plastic centrifuge tubes and centrifuged at 3000 rpm for 10 min. The supernatant was pipetted out leaving behind only a residual material at the bottom of tube. This residual material was suspended in distilled water and again centrifuged in the same way to ensure that even the traces of acid were removed. The 'cleaned' diatom frustule containing diatoms was spread and allowed to dry on five serially marked (I–V) microscopic slides (for each side of water body) and then mounted permanently with DPX.[10] Slides were examined with an optical compound microscope fitted with light source at different magnifications up to 1500 × oil immersion and photomicrographs were captured using a computerized photo-capturing device/camera (Q-Win Leica) fitted in the microscope. Diatom *species* were identified on the basis of available literature.[2,8] Slides were examined and data was recorded in a specially designed *Database Record Chart* (Table 2). Some of the photomicrographs of diatoms have been shown in Table 3.

2.3. Quantitative distribution of diatoms

Criteria for calculating the percentage of a particular *genus* was standardized by randomly counting first hundred diatoms on the permanent slides prepared for each side of every water body. The genera were identified and classified to calculate the average percentage of a particular genus on each side of water body, which was finally used to calculate the percentage of each genus in a particular water body. Diatoms were divided into six major groups. The first five groups were selected on the basis of the most commonly found diatoms i.e. *Group-1* (*Navicula*), *Group-2 (Nitzschia), Group-3 (Cyclotella), Group-4 (Synedra), Group-5* (*Melsoira*) and the last *Group-6* was named as 'others' that included all the remaining diatom genera of a water body.

2.4. Generating diatomological maps (D-Map)

On the basis of above observations, the profiles of diatom flora of selected water bodies were generated. The season wise record of diatom was studied and compared thoroughly. Various commonly

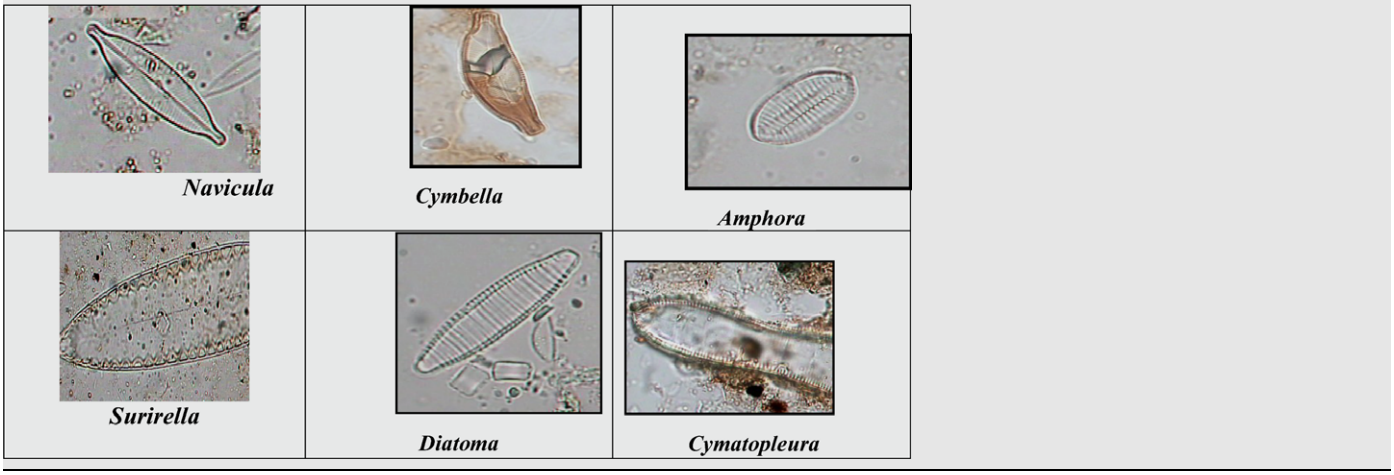
Table 1
Showing some physical and chemical characteristics of the selected water bodies.

Name of the site	Type of water body	Type of area	Depth in feet	Water pH (average)
1. SL, CHD	Lake	Foot hills	100–110	7.8
2. SWB, RPR	River dam	Foot hills	900–1000	7.0
3. KW, KPT	Canal	Plain	160–175	8.3
4. NWS and W, HRK	River	Plain	900–1000	7.6
5. GNDTP, BTI	Pond	Plain	40–50	6.2
6. MBB, PTA	Canal	Plain	80–100	7.3
7. KDT, PTA	Pond	Plain	25–30	6.5
8. IGC, MKT	Canal	Slightly desert	300	7.8
9. BD, NGL	River	Hilly	Above 1000	7.1
10. PD, TLR	River	Foot hill	900–1000	7.2

Table 2
Showing database record chart (specimen for each water body).

Side of the water body	Slide I		Slide II		Slide III		Slide IV		Slide V	
	Diatom species	Size (μm)	Diatom species	Size (μm)	Diatom species	Size (μm)	Diatom species	Size (μm)	Diatom species	Size (μm)
Side-A										
Side-B										
Side-C										
Side-D										

Table 3
Showing photomicrographs of the identified diatom genera.



occurring, seasonal and rare or site-specific diatoms *species* were noted.

The Diatomological map (Table 8) consists of the following three parts:

Part-1 Table showing characteristic distributions of

- *Commonly occurring diatoms*
- *Seasonal diatoms*
- *Rarely occurring diatoms*
- *Site-specific diatoms*

Part-2 shows Photomicrograph of some site indicator diatoms and

Part-3 Histogram showing qualitative and quantitative distributions of diatoms in different seasons in a water body.

3. Results and discussions

Distribution of diatoms based on both season and site specific has been studied in detail. The results of the present study showed that water conditions and seasonal changes are generally important factors affecting changes in the distribution of diatoms across the broad geographical region (Table 6). Morphological Analysis of Diatoms revealed 51 *genera* and 126 diatom *species*, and most of them belonged to order "*Pennales*" with few exceptions of "*Centrale*" diatoms. Some important morphological observations have been given in Table 5.

3.1. Variations in shape and size of diatoms

Morphometric analysis of diatoms has revealed significant variation in their shape and size. The shapes of most of the diatoms found in the selected water bodies were elliptical but few diatoms were rods like and oval in shape. Most of the large diatoms were elongated and elliptical in shape. *Synedra* and *Diadesmis* were rod like diatoms and beautiful *Cocconeis* had an oval shape. With the few exceptions, *Amphipleura* (needle shape), *Cymatopleura* (shoe shape) and *Gyrosigma* (sigmoid shape) were peculiar in their shapes (Table 4). Similarly, it was observed that the size of diatoms also varies with the conditions. Water bodies with stagnant water conditions generally had small size diatoms while large size diatoms were usually present in flowing water. Few diatom genera like *Achhnanthidium, Hannaea* and *Rhopalodia* were measured very small in size (5–10 μm) whereas Size of *Synedra, Melosira* and *Cymatopleura,* were mostly gauged above 100 μm. These diatoms were found in canals and other water flowing channels (Table 5).

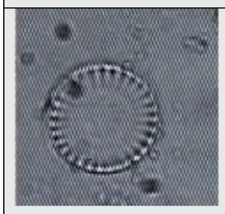
3.2. Distribution pattern of other types of diatoms

In the present study, *Navicula, Nitzschia, Cyclotella, Synedra* and *Melosira* were commonly found in all the selected water bodies but their frequency was observed varying both season and site wise. Diatoms such as *Aulacoseira, Craticula, Pseudostaurosira* and *Staurioneis* were rarely present. Another category included those diatoms, which were *site specific* and consistently associated with a particular site irrespective of season. For example the diatoms such as *Hannaea* and *Rhoicosphenia* were seen only in Sukhna Lake throughout the year. *Cymatopleura solea, Didesmis splenda, Gyrosigma spencerii* and *Geissleria declivis* were also site indicator diatom *species*.

3.3. Season wise qualitative distribution of diatoms

There is a clear distribution of the seasons in Punjab. Noticeable divergences in the seasonal distributional of diatom *species* were recorded in the selected water bodies. It was observed that diatom

Table 4
Photomicrographs showing some peculiar shape differences in diatoms.

Circular	Oval	Elliptical	Elongate
			
Rod	**Sigmoid**	**Shoe**	**Needle**
			

blooms follow a prototype seasonal periodicity. Similar observation was also made by.[12] Winter season has short days, and temperature declines to even lower than 0 °C. Intensity of natural light remains very low and conditions are mostly dry. Generally winter had a 'dilution effect' on diatom diversity because climatic conditions are not favorable for the growth of diatoms therefore very low population of diatoms exists in winter. *Cocconeis* is the characteristic diatom of this season. But a substantial diatom bloom occurs in autumn season when range of temperature increased from 20 °C to 35 °C, and a huge amount of natural light helps in photosynthesis and ultimately in growth of a variety of diatoms. A significant change in the qualitative and quantitative distribution of diatoms takes place in warm summer season. Due to the higher temperature (above 45 °C) growth conditions of diatoms follow a very slow and tidy pace. *Gomphoneis species* exist as a characteristic diatom in this season. Due to favorable climatic conditions in spring season, a full bloom of diatoms takes place. Along with common diatoms a variety of rare diatom *species* also grow in these conditions. *Synedra* and *Cymbella* are the characteristic diatoms of this season. Earlier Diatomological studies related to Indian region[1,10,12] have shown almost similar results.

4. Quantitative analysis of diatom distributions

Distribution pattern of diatoms (only five of the genera in the present study) has shown characteristic variation among the selected sites. Most commonly found diatoms (*Navicula, Nitzschia, Cyclotella, Melosira, Synedra, Cocconeis, Cymbella* and *Nitzschia*) have been observed in almost every water body but their quantity was found to be varying in different seasons. Few diatoms (which are called *indicator diatom species* or *site-specific* diatom *species*) were restricted to particular sites only (Tables 5 and 7). *Navicula* was the most dominating diatom in the selected water bodies and *Cocconeis* was commonly found diatom in winter season, but in terms of concentration only *Melosira* was found at peak maxima in the winter season. *Nitzschia* also grows in most of the water bodies with considerably varying concentration. Overall seasonal periodicity of occurrence of diatoms has been detailed in the Table 7 and Histogram 1.

4.1. Classification of water bodies based upon diatom distributions

Characterization of water bodies was made on the basis of the analysis of diatom taxa. Only diatom *species* with the high consistency and specificity were considered as *indicator diatom species* or *site specific species*.

4.2. Sukhna Lake, Chandigarh (D-Map-1) with exemplified diatomological maps

Sukhna Lake is situated in the foothills of Shivalik Himalayan Mountains range. Water of this lake is a modestly contaminated, and produces two noticeable diatom *species* i.e. *Rhopalodia gibba* and *Hannaea arcus*. These are *indicator diatom species* of this lake because they are site-specific and occur consistently in all four seasons. Other diatoms *species* like *Navicula, Achhnanthidium breviceps, Epithemia adnata, Cyclotella kuetzingiania and Cyclotella mengeniana* have also been observed. *Pinnularia burkii, Synedra ulna* occurs in autumn, while *Nitzschia palea, Encyonema gracile and Encyonema minutum* present in winter seasons in abundance. *Rhoicosphenia curvata* is a seasonal diatom of this water body.

Exemplified Diatomological Maps of Sukhna Lake, Chandigarh has been given Table 8 (Part-1 (Table), Part-2 (Photomicrograph) and Part-3 (Histogram 2)).

In the same way the D-Map for other water bodies can also be generated.

5. Diatomological descriptions of other water bodies

5.1. Sutlej Water Body, Ropar

Quality of water samples collected from this water body was good in comparison to other water bodies. This water body has pH of 7 and a vast diversity of fine-looking and hefty diatom such as *Frustulia*, *Amphipleura*, *Gomphocymbella*, *Cymbella* and *Gomphonema*. Few *Gomphonema species* (*G. tumens*, *G. variabilis*, *G. olivacea* and *G. gracile*, etc.) were seen only in this water body. These diatoms were consistently present with a noteworthy concentration during all four seasons. *Diploneis ovalis* and few *Placoneis species* were also found associated with this water body especially during

Table 5
Showing some morphological and morphometric details of the identified diatoms.

Diatom Genus	Length (μm)/diameter (circular)	Width (μm)	Shape (valve view)
1. *Achnanthes*	8–16	4–6	Elliptical
2. *Achhnanthidium*	18–30	11–14	Elliptical
3. *Actinocyclus*	36–40		Circular
4. *Amphipleura*	80–140	7–9 μm	Elongate
5. *Amphora*	30–105	17–50 μm	Elliptical
6. *Anomoeoneis*	25–200	12–60 μm	Elliptical
7. *Aulacoseira*	45–50		Circular
8. *Caloneis*	22–50	10–14	Elliptical
9. *Campylodiscus*	25–30		Circular
10. *Catacombus*	80–100	5–9	Elongate
11. *Cavinula*	15–25	15–25	Elliptical
12. *Chamaepinnularia*	45–65	15–20	Elliptical
13. *Cocconeis*	12–54		Oval
14. *Coscinodiscus*	26–30		Circular
15. *Craticula*	44–75	25–30	Elliptical
16. *Cyclostephanos*	22–26		Circular
17. *Cyclotella*	15–30		Circular
18. *Cymatopleura*	80–300	10–45	Shoe
19. *Cymbella*	20–200	5–50	Elliptica
20. *Diadesmus*	30–45	4–10	Rod
21. *Diatoma*	18–60	8–18	Elliptical
22. *Diploneis*	10–40	6–10	Elliptical
23. *Encyonema*	20–60	4–9	Elliptical
24. *Epithemia*	40–50	8–10	Elliptical
25. *Eucocconeis*	35–40		Oval
26. *Eunotia*	22–28	5–10	Elliptical
27. *Fragilaria*	50–70	10–14	Elliptical
28. *Frustulia*	60–85	10–18	Elliptical
29. *Geissleria*	36–40	16–20	Elliptical
30. *Gomphoneis*	15–130	12–20	Elliptical
31. *Gomphonema*	74–90	16–20	Elliptical
32. *Gyrosigma*	150–240	26–30	Sigmoid
33. *Hannaea*	18–30	4–8	Elliptical
34. *Hantzschia*	80–120	18–22	Elongate
35. *Melosira*	100–250	8–12	Rod
36. *Navicula*	10–30	5–16	Elliptical
37. *Neidium*	40–50	10–15	Elliptical
38. *Nitzschia*	25–110	5–10	Elliptical
39. *Pinnularia*	20–150	8–18	Elliptical
40. *Placoneis*	20–30	10–12	Elliptical
41. *Pleurosira*	10–15		Circular
42. *Pseudostaurosira*	12–22	6–8	Elliptical
43. *Rhoicosphenia*	16–30	8–10	Elliptical
44. *Rhopalodia*	12–18	4–8	Elliptical
45. *Stauroneis*	70–100	14–20	Elliptical
46. *Stenopterobia*	80–100	8–16	Sigmoid
47. *Stephanodiscus*	26–30		Circular
48. *Surirella*	40–70	30–40	Elliptical
49. *Synedra*	100–200	3–7	Rod
50. *Tabellaria*	20–30	10–20	Elliptical
51. *Thalassiosira*	15–20		Circular

autumn season while *Eucoccoenis* was seen only in summer season. *Gomphoneis* was also seen here during summer season.

5.2. Kanjli Wetland, Kapurthala

Water of this water body is contaminated due to some pollution linkages. Varieties of diatom *species* have been observed in the water samples from Kanjli Wetland, Kapurthala. Autumn season remains full of diatoms. *Diadesmis*, *Neidium affine* were found to be *indicator diatom species*. *Cocconeis placentula, Cyclotella comensis, Cymbella cistula, Diatoma vulgare, Epithemia advata, Pinnularia* and *Synedra ulna* were other commonly existing diatom *species*. Few *Achhnanthidium* and *Amphora species* seemed to be integral part of this site in autumn season only. Some of the rare *species* of *Cavinula* had also been found here.

5.3. National Wildlife Sanctuary & Wetland Harike

Cymatopleura solea, Pinnularia globiceps and Geissleria declivis were the indicator diatom species or site-specific diatom species of National Wildlife Sanctuary & Wetland Harike water body. *Geissleria species* was not found consistently. Other diatom species like *Synedra delicatissima, Eunotia plexuosa, Gyrosigma spencerii* and *Hantzschia amphioxys* were also noticed in this water body. *Anomoeoneis* was observed consistently in spring season.

5.4. Guru Nanak Dev Thermal Plant, Bathinda

Even in diatom favorite seasons no significant diatom population was recorded here in the ponds of Guru Nanak Dev Thermal Plant, Bathinda water body because of highly contaminated water. *Cyclotella, Cymbella* and *Melosira species* were seen throughout the year in low concentration. *Tabellaria* was also seen here in spring season. *Surirella* and *Campylodiscus* was the peculiar diatom of this water body but are not consistent.

5.5. Main Bhakra Branch, Patiala

This canal carries clean water and fast flow of water do affects the quality of the diatom community. Interesting feature of this water body was that it brings into being a diatom mesh but could not provide any specification to this water body. Most of the diatoms came in spring season and hardly any in winter season. Water of this site carries *Diatoma, Synedra, Cymbella* and *Nitzschia* in it but other common types of diatoms like *Navicula* and *Cyclotella* were not observed consistently.

5.6. Kali Mata Mandir Pond, Patiala

This is a small pond is situated in front of the Kali Mata Mandir of Patiala city. Water is polluted due to unwanted vegetation and some external pollution resources. *Actinocyclus* and *Coscinodiscus* were seen in summer and winter season, respectively. *Melosira*, and *Nitzschia* have been found the commonly occurring diatoms in this water body. Along with this some *species* of *Navicula, Synedra* and *Cyclotella* were also viewed. This water body produced considerable amount of diatoms even in the substandard climatic conditions.

5.7. Indira Gandhi Canal, Lambi, Mukatsar

This canal originates from National Wildlife Sanctuary & Wetland Harike with no outlet on the way up to Rajasthan. This is an ideal water body of healthy seasonal distribution of diatoms. Full blooms of diatoms exist not only in favorable but also during unfavorable climatic conditions. Varieties of diatom *species* were recovered from this site. Hefty *Nitzschia* was ever the dominant diatom *species*, while negligible presence of *Navicula* was peculiarity of this water body.

Eunotia subarcuatoides, *Caloneis amphisbaena* and *Craticula cuspidate* were the indicator diatom species or site-specific diatom species. Diatom species of *Achnanthes*, *Cyclotella*, *Melosira* and *Cymbella* were commonly found throughout the year. Winter season also produced few *Cocconeis species*. *Stenopterobia* and *Stephanodiscus* were seen only in summer season.

5.8. Bhakra Dam, Nangal

This is a major water body, which is located near the border of Punjab and Himachal Pradesh near Nangal city. There is no significant seasonal distribution of diatom diversity. This water body

Table 6
Showing distribution pattern of Diatoms in all 10 water bodies.

Diatom genus	WB*1	WB*2	WB*3	WB*4	WB*5	WB*6	WB*7	WB*8	WB*9	WB*10
Achnanthes	–	–	–	–	–	–	–	+	–	–
Achhnanthidium	+	–	–	–	–	–	–	–	–	–
Actinocyclus	–	–	–	–	–	–	+	–	–	–
Amphipleura	–	+	–	–	–	–	–	–	–	–
Amphora	–	–	+	–	–	–	–	–	–	–
Anomoeoneis	–	–	–	+	–	–	–	–	–	–
Aulacoseira	–	–	–	–	–	+	–	–	–	–
Caloneis	–	–	–	–	–	–	–	+	–	–
Campylodiscus	–	–	–	–	+	–	–	–	–	–
Catacombus	–	–	+	–	–	–	–	–	–	–
Cavinula	–	–	+	–	–	–	–	–	–	–
Chamaepinnularia	–	–		+	–	–	–	–	–	–
Cocconeis	+	–	+	–	–	–	+	+	+	+
Coscinodiscus	–	–	–	–	–	–	+	–	–	–
Craticula	–	–	–	–	–	–	–	+		
Cyclostephanos	–	–	–	–	–	–	–	–	–	+
Cyclotella	+	+	+	+	+	+	+	+	+	+
Cymatopleura	–	–	–	+	–	–	–	–	–	–
Cymbella	+	+	+	+	+	+	–	+	+	–
Diadesmus	–	–	+	–	–	–	–	–	–	–
Diatoma	+	–	+	–	–	+	–	–	+	–
Diploneis	–	+	–	–	–	–	–	–	–	–
Encyonema	+	–	–	–	–	–	–	–	–	–
Epithemia	+	–	+	–	–	–	–	–	–	–
Eucocconeis	–	+	–	–	–	–	–	–	–	–
Eunotia	–	–	–	+	–	–	–	+	–	–
Fragilaria	–	–	–	–	–	–	–	–	–	+
Frustulia	–	+	–	–	–	–	–	–	–	–
Geissleria	–	–	–	+	–	–	–	–	–	–
Gomphoneis	–	+	–	–	–	–	–	–	–	–
Gomphonema	–	+	–	+	–	+	–	–	–	–
Gyrosigma	–	–	+	+	–	–	–	–	–	–
Hannaea	+	–	–	–	–	–	–	–	–	–
Hantzschia	–	–	–	+	–	–	–	–	–	–
Melosira	+	+	+	+	+	+	+	+	+	+
Navicula	+	+	+	+	+	+	+	+	+	+
Neidium	–	–	+	–	–	–	–	–	–	–
Nitzschia	+	+	+	+	+	+	+	+	+	+
Pinnularia	+	+	+	+	–	–	–	–	–	–
Placoneis	–	+	–	–	–	–	–	–	–	–
Pleurosira	–	–	–	–	–	–	–	–	+	–
Pseudostaurosira	+	–	–	–	–	–	–	–	–	–
Rhoicosphenia	+	–	–	–	–	–	–	–	–	–
Rhopalodia	+	–	–	–	–	–	–	–	–	–
Stauroneis	+	–	–	–	–	–	–	–	–	–
Stenopterobia	–	–	–	–	–	–	–	+	–	–
Stephanodiscus	–	–	–	–	–	–	–	+	–	–
Surirella	–	–	+	–	+	–	–	–	–	–
Synedra	+	+	+	+	+	+	+	+	+	+
Tabellaria	–	–	–	–	+	–	–	–	–	–
Thalassiosira	–	–	–	–	–	+	–	–	–	–

+: Present.
–: Absent.
* WB – water body.

Table 7
Showing seasonal periodicity of occurrence of diatoms in different seasons.

	Navicula	*Nitzschia*	*Synedra*	*Cyclotella*	*Melosira*	Others
Summer	25	17	8	10	11	29
Spring	21	10	18	8	8	35
Winter	18	10	18	8	32	14
Autumn	28	12	12	10	16	22
Total (%)	23	12.25	14	9	16.75	25

carries seasonal distinguishable diatoms such as *Pleurosira minor* found in autumn season. *Diatoma, Navicula, Cyclotella* and *Cymbella* were the other commonly found genus of diatoms. *Cocconeis* was the most consistently occurring diatom while *Nitzschia* and *Melosira* were hardly seen here.

5.9. Pond Dam, Talwara

This is second major water body, which is situated near Talwara town. Water is pure and clear. There is no pollution or industrial linkage. Water samples from this site do not provide anything worth notable. *Cyclostephanos* and *Fragilaria* were seen during winter season only. Apart from some commonly found diatoms like *Navicula, Synedra, Melosira, Cyclotella* and *Nitzschia* nothing peculiar was found.

6. Conclusions

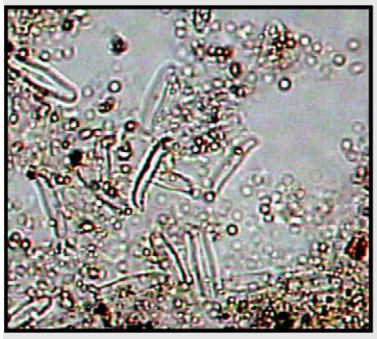
The site specific/indicator diatoms exist consistently during all seasons but their percentage keeps on changing depending upon the season in any particular water body. These *diatom species* were

Table 8
Showing exemplified diatomological map of Sukhna Lake, Chandigarh (Part-1, -2 and -3).

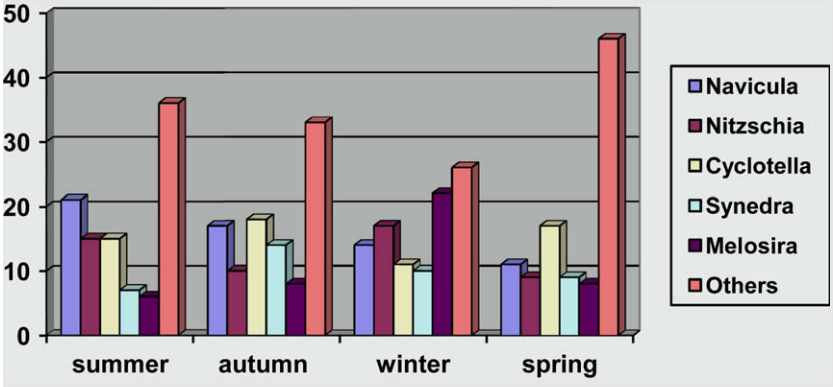
Part-1: Table showing some characteristic diatom species distributions

Commonly occurring diatoms	Seasonal diatoms	Rarely occurring diatoms	Site-specific diatoms	Remarks
Achnanthidium lanceolata *Cocconeis pediculus* *Cyclotella comemsis* *Navicula virdual* *Nitzschia recta* *Melosira variance* *Diatoma hiemale* Synedra ulna	*Epithemia* *adnata* *Pinnularia tenuis* *Encyonema* *Cymbella*	*Pseudostaurosira* *Stauroneis*	*Rhopalodia gibba* *Hannaea arcus*	Few site-specific diatoms species occur consistently throughout the year

Part-2: Photomicrograph showing some site-specific diatoms



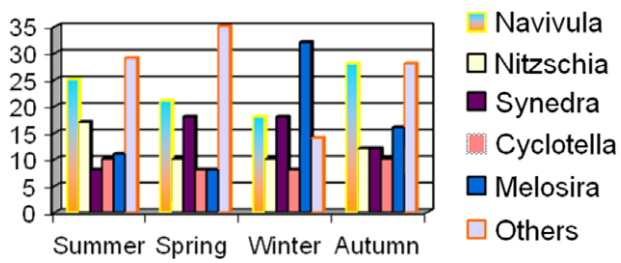
Part-3: Histogram 2 showing qualitative and quantitative distributions of diatoms in different seasons (these are the average values taken after counting 100 diatoms)



mostly seen in the Lakes with stagnant water conditions, but were mostly absent in running water channels like canals, etc.

In the present study, all the information was updated in the form of *Diatomological Maps* (*D-Map*) for every water body. Each *D-Map* will provide significant information not only regarding the *commonly occurring, seasonal, rarely occurring and site-specific diatoms* but also gives qualitative and quantitative distributions of diatoms in different seasons in a particular water body.

So, it is hoped that the concept of developing *D-Map* for a specific water body will be of immense help in enhancing the current knowledge of Forensic diatomology and provides useful lead to the forensic scientists in solving the drowning cases.



Histogram 1. Showing percentage of some commonly occurring diatom genera in all four seasons of two years.

Conflict of Interest

None declared.

Funding

None declared.

Ethical Approval

None declared.

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